BI-LAYERED ELECTROSPUN AND MELT ELECTROWRITEN PCL CONSTRUCT AIMING TOWARDS A PROSTHETIC VASCULAR GRAFT

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Introduction

Blood vessels are the highway of the cardiovascular system, transporting blood and nutrients. Narrowing or total occlusions [1] are often a failure cause, frequently necessitating a vascular graft. While large-diameter prosthetic vascular grafts have a relatively good outcome, the small-diameter grafts tend to fail as they largely remain without endothelium [2]. To improve the outcome when a vascular replacement is needed, new suitable artificial vascular grafts with favorable biological and biomechanical properties are vital.

Melt-electrowriting (MEW) is a relatively new biofabrication technique that allows for the creation of micro-fibrous polymer scaffolds by precise layer-by-layer deposition. This enables a controlled structure which further leads to more use case defined mechanical properties, tailored to vascular graft requirements. While MEW gives good control over the mechanical properties, it is typically too porous. In combination with solution-electrospinning (SES), lower porosity layers can be incorporated as SES produces denser membranes with thinner fibres.

The aim of this study was to characterise the effect of an SES membrane either on the inside (imitating a tunica intima) or the outside (imitating a tunica externa) with a microfiber grid MEW layer as the main structural component.

Methods

Three combinations of tubular scaffolds were created by either an in-house developed MEW setup or in combination with solution-electrospinning (SES). Group1 was a MEW microfiber layered grid, Group2 was the same MEW grid with a thin electrospun layer outside while Group3 had a thin electrospun layer inside the MEW grid. A total of n = 3 specimens were tested for each group.

Microscopy and optical profilometry were used to assess the fiber diameter and scaffold wall thickness. A quasi-static tensile test was performed in the longitudinal and circumferential directions of the tubular scaffold to evaluate the mechanical properties.

Results

The scaffold wall thickness for Group 1 was 188.3µm (SD=21.8µm), while for Groups 2 and 3 it was 208.0µm (SD=21.8µm). The stresses observed in the circumferential (yield) and longitudinal (at 1.7% strain) testing direction were 0.27 (SD0.01) MPa, 0.30 (SD0.01) MPa and 0.28 (SD0.01) MPa and 0.22 (SD0.01) MPa, 0.41 (SD0.01) MPa and 0.36 (SD0.01) MPa for Group1, Group2 and Group3, respectively.

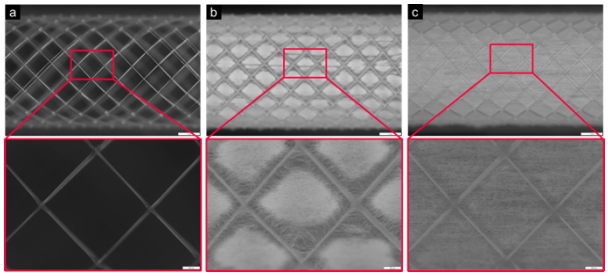

Figure 1: Stereomicroscope images of tubular scaffolds of all three groups. a) Group1 with just a MEW scaffold. b) Group2 with SES outside the MEW scaffold. b) Group3 with SES inside the MEW scaffold.

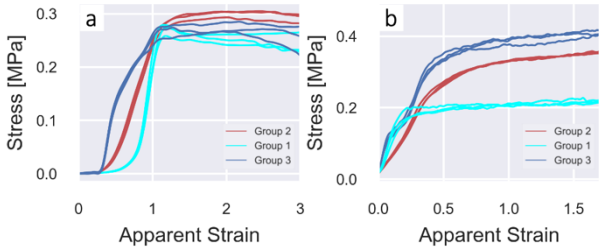

Figure 2: Stress-Strain curves for all three groups in two tensile testing directions. a) Circumferential tensile test. b) Longitudinal tensile test.

Discussion & Conclusions

The addition of an inner or outer SES layer influences the behavior of the scaffold, especially below 100% strain. In the circumferential testing direction, we did not see a substantial increase in yield stress with the additions of an SES layer, however the toe region was shorter and the scaffold response was initially stiffer. Combining SES with MEW resulted in higher maximum stresses for both Group2 and Group3, but especially the combination of MEW on SES, where the maximum stress was almost doubled for the longitudinal direction compared to only MEW. While we have shown that adding an SES layer can increase mechanical properties and change the response in certain strain intervals, depending on the location of that layer, the mechanical properties are still considerably lower than values measured for native vascular tissue, therefore further development is required.

References

1. Irving J, Curr Cardiol Rev., 10:99-107, 2014.
2. Zilla et al, Biomaterials, 28:5009-27, 2007.